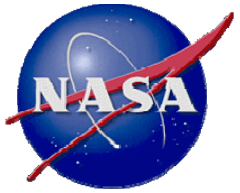
National Aeronautics and Space Administration



Orbital Debris Program

J.-C. Liou, PhD
NASA Chief Scientist for Orbital Debris

For HEOMD OMB Examiner Visit to JSC
7 April 2016

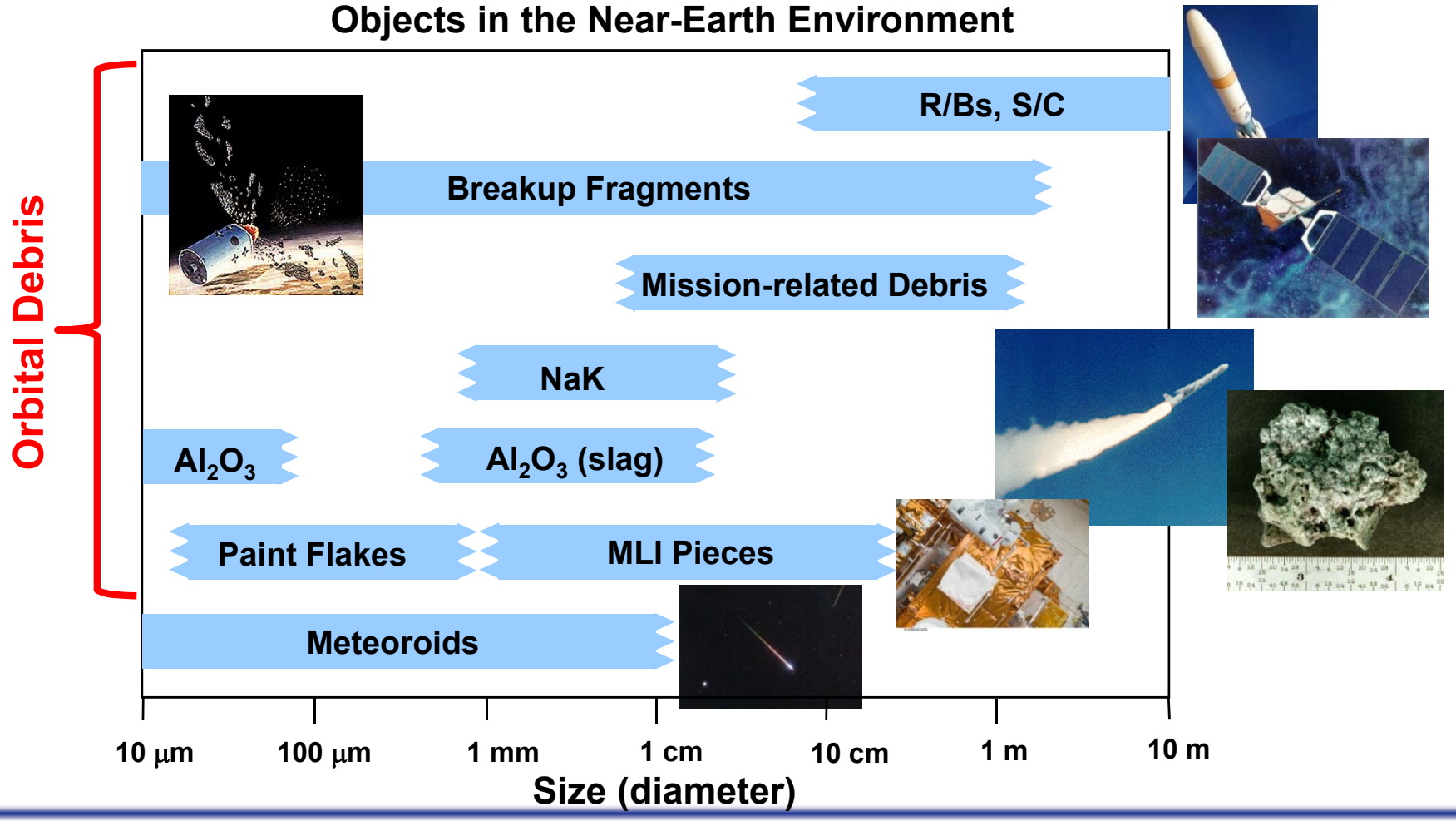
Outline

- **Overview of the orbital debris problem**
  - What is orbital debris
  - Danger of orbital debris
- **NASA Orbital Debris Program Office**
  - Roles and responsibilities
  - Highlights of its recent research activities
- **Orbital debris mitigation policy**
  - NASA
  - U.S. Government
  - International community (IADC and United Nations)

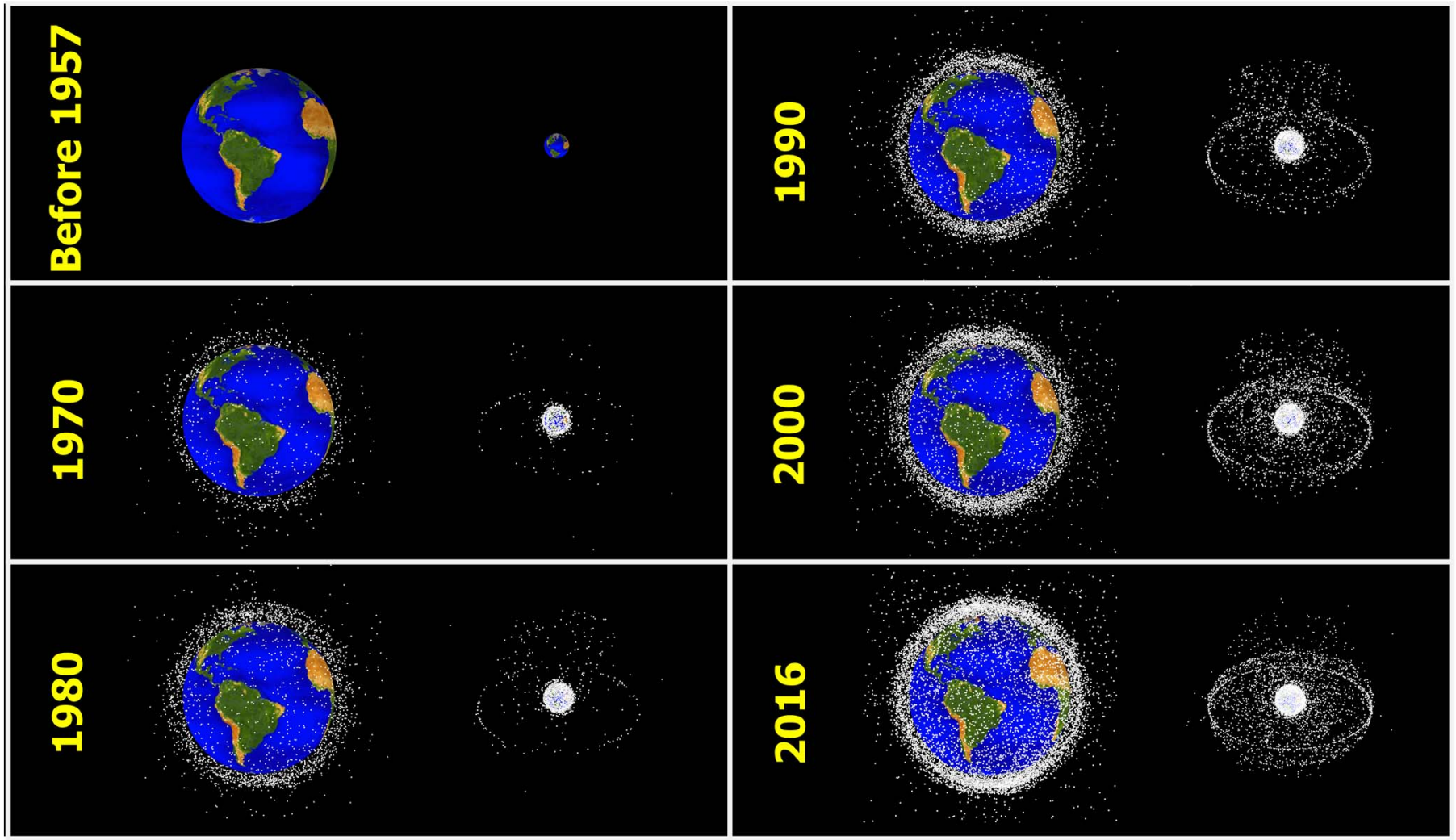
Overview of the Orbital Debris Problem

What Is Orbital Debris?

- **Orbital debris is any human-made object in orbit about the Earth that no longer serves any useful purpose**



Historical Orbital Debris Environment



- Only objects in the U.S. Space Surveillance Network (SSN) catalog are shown
- Sizes of the dots are not to scale

How Much Junk Is Currently Up There?

Softball size or larger (≥10 cm): ~23,000
(tracked by U.S. Joint Space Operations Center, JSpOC)

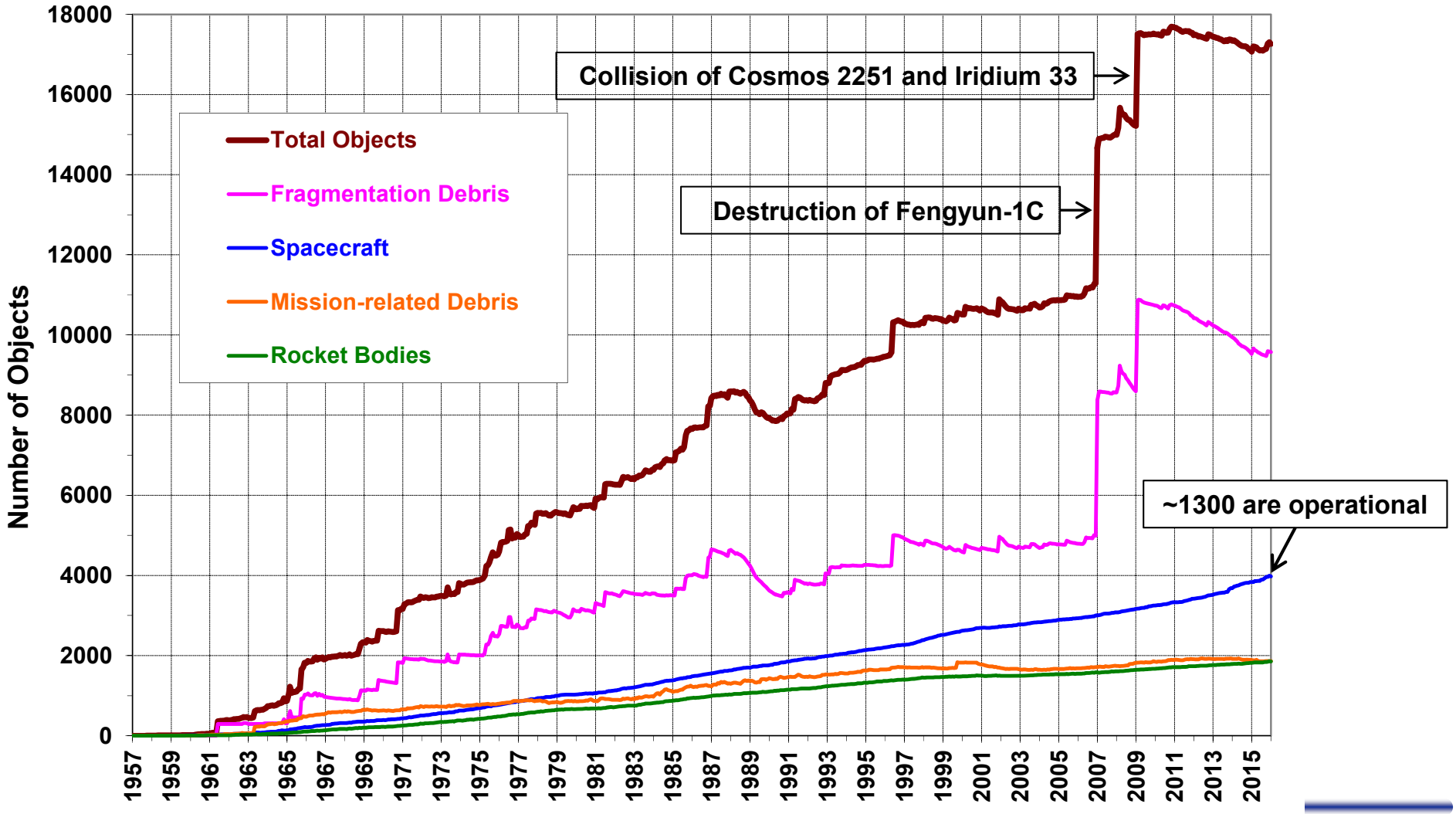
Marble size or larger (≥1 cm): ~500,000

Dot or larger (≥1 mm): >100,000,000
(a grain of salt)

- **Due to high impact speed in space (~10 km/sec in LEO), even sub-millimeter debris pose a realistic threat to human spaceflight and robotic missions**
  - **10 km/sec = 22,000 miles per hour (the speed of a bullet ~1,500 miles per hour)**
- **Total mass: >7000 tons LEO-to-GEO (~2700 tons in LEO)**

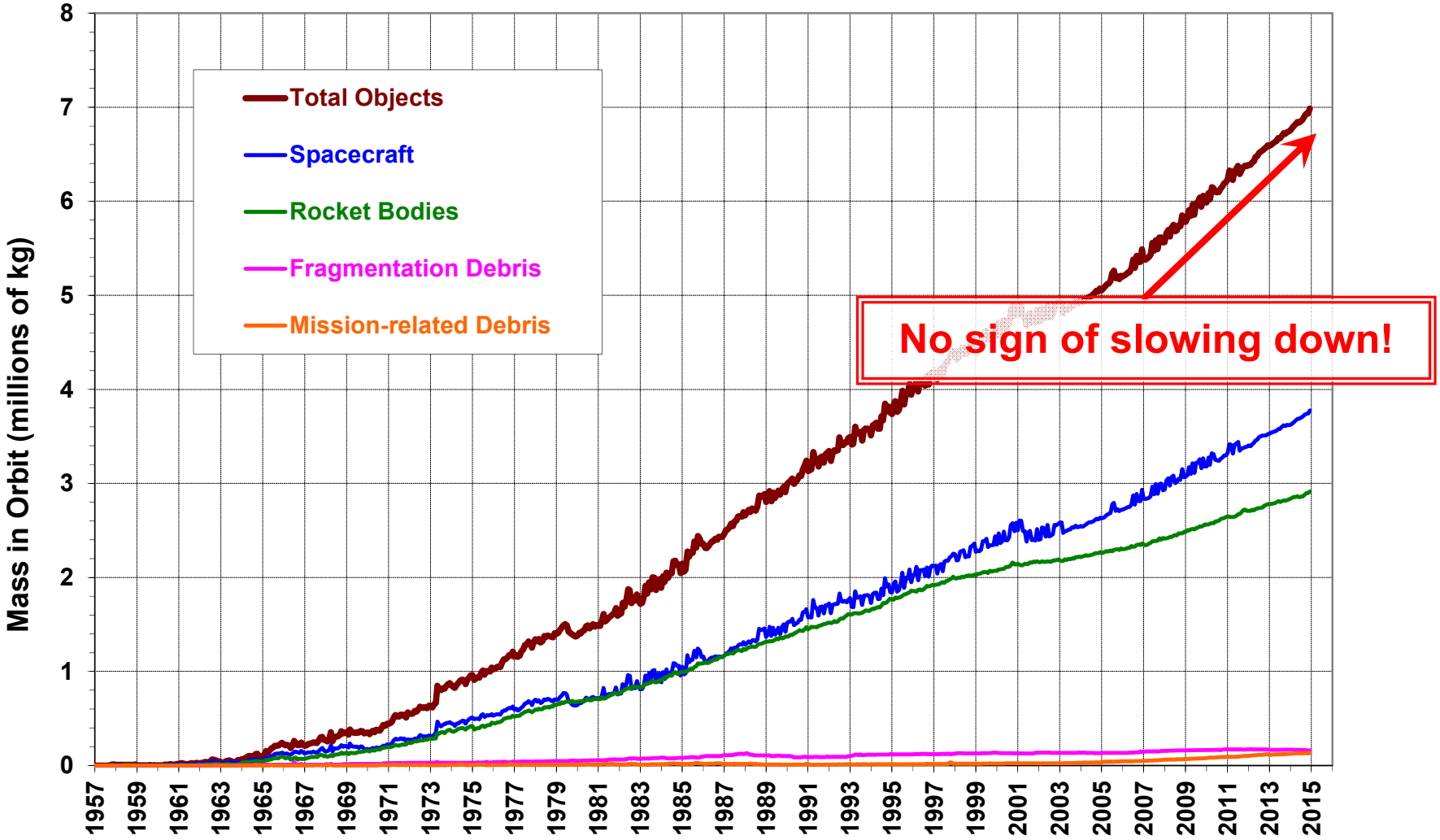
Growth of the Cataloged Populations

- **JSpOC is tracking ~23,000 large objects and maintains most of their orbits in the U.S. Satellite Catalog**



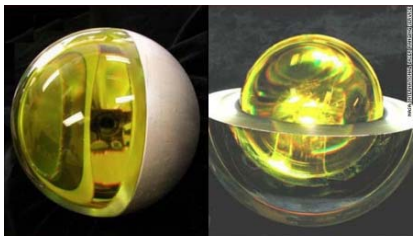
Mass in Orbit Continues to Increase

- **The material mass in Earth orbit continues to increase and has exceeded 7000 metric tons**

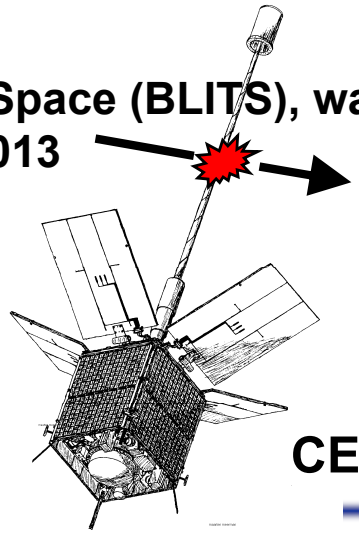


Threat from Orbital Debris

- **The threat from orbital debris**
  - The gravity-gradient boom of an operational French satellite (CERISE) was cut in half by a tracked debris fragment in 1996
  - The fully operational Iridium 33 was destroyed by a retired Russian satellite (Cosmos 2251) in 2009
  - Near the end of the Space Shuttle Program, the Loss of Crew and Vehicle risks from MMOD impact damage were in the range of 1-in-250 to 1-in-300 per mission (OD to MM ~2:1 at ISS altitude)
  - Impacts by small, untracked debris could be responsible for many satellite anomalies
    - **A 17-cm Russian retro reflector, Ball Lens In The Space (BLITS), was damaged and shed a piece of trackable debris in January 2013**



BLITS



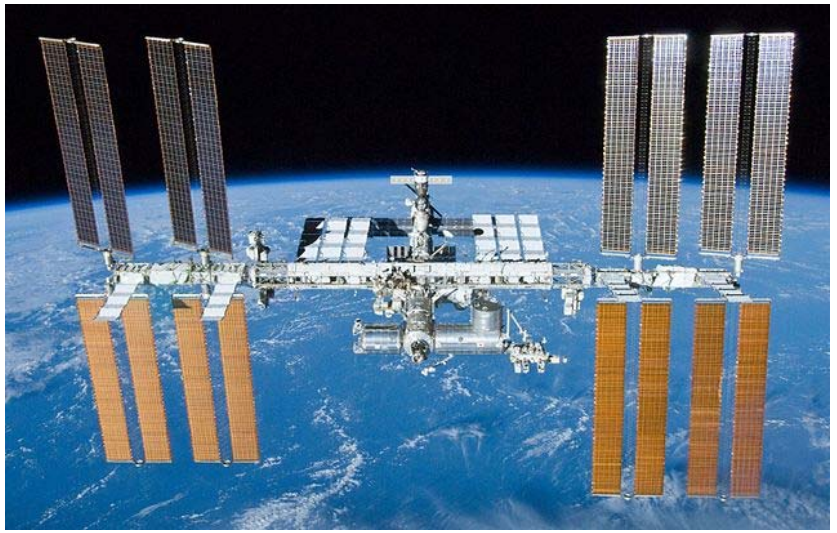
CERISE

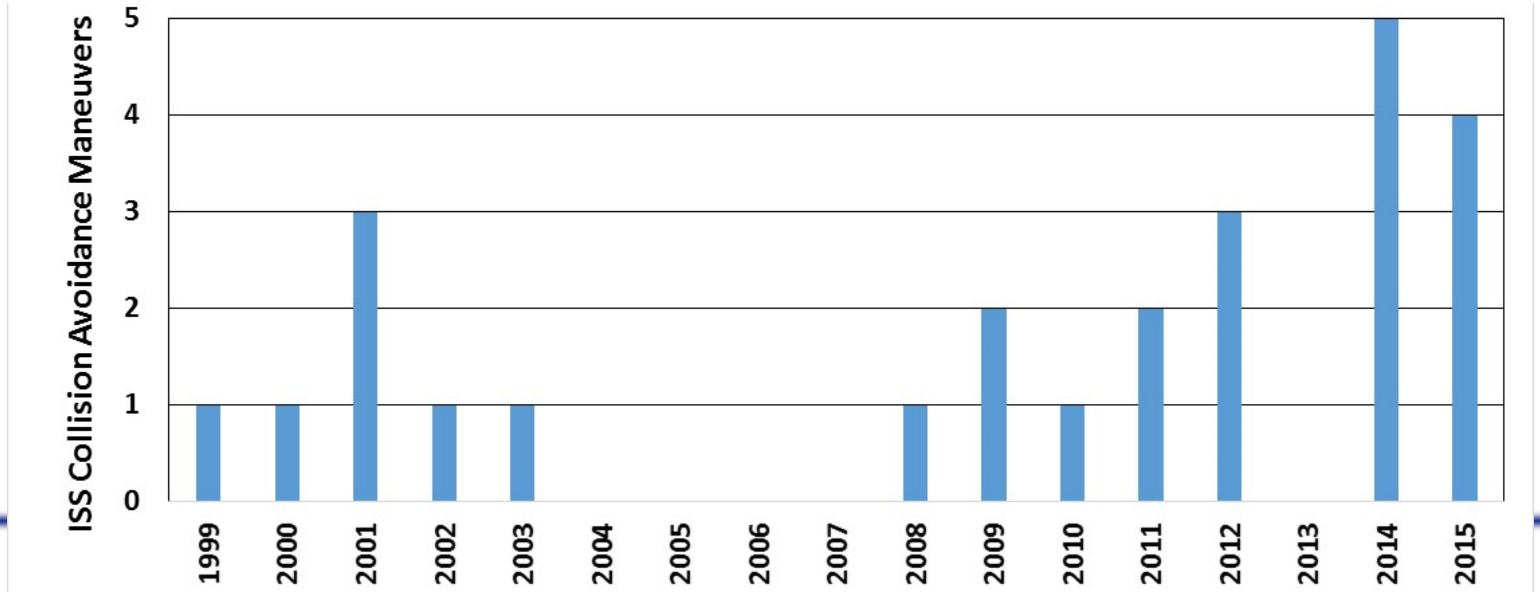
Robotic Spacecraft Collision Avoidance Maneuvers

- **Since 2007 NASA has required frequent satellite conjunction assessments for all of its maneuverable spacecraft in LEO and GEO to avoid accidental collisions with objects tracked by JSpOC**
  - Led by the Conjunction Assessment Risk Analysis (CARA) team at GSFC
- **NASA also assists other U.S. government and foreign spacecraft owners with conjunction assessments and subsequent maneuvers**
- **During 2015 NASA executed or assisted in the execution of 26 collision avoidance maneuvers by robotic spacecraft**

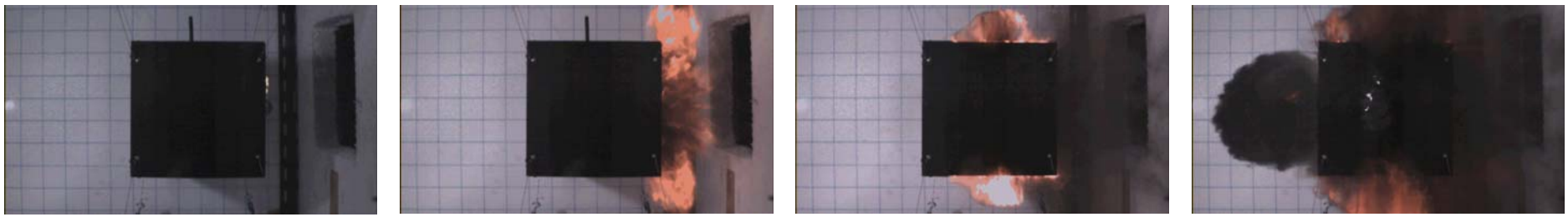
ISS Collision Avoidance Maneuvers

- **The International Space Station (ISS) conducted four debris collision avoidance maneuvers in 2015**
- **In addition, due to a late notification of a high probability conjunction, the crew was directed to "shelter-in-Soyuz" on July 16th**
  - Fortunately the conjunction did not lead to a collision

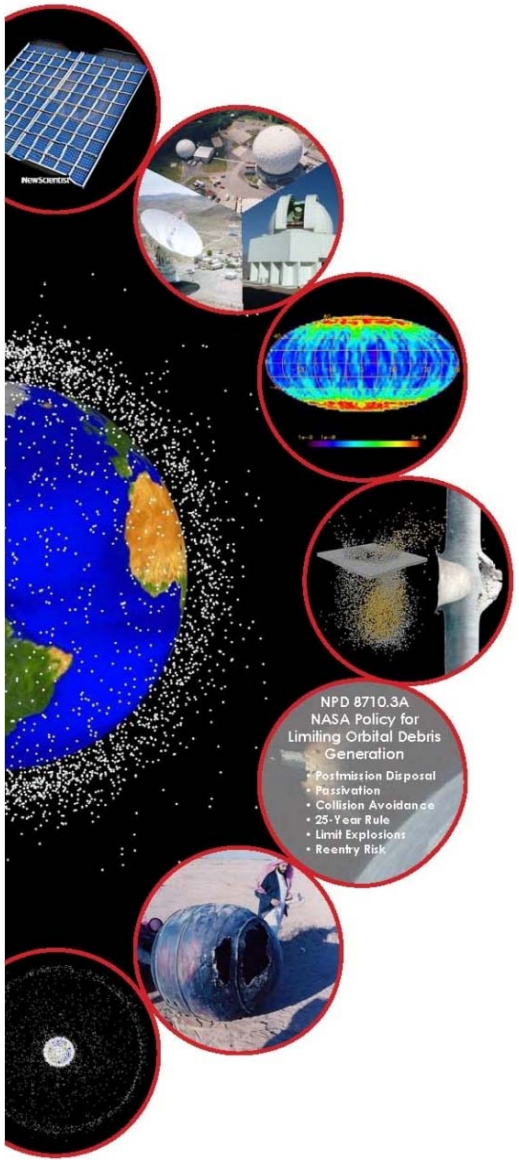




The NASA Orbital Debris Program Office

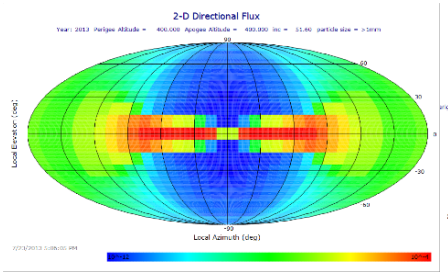


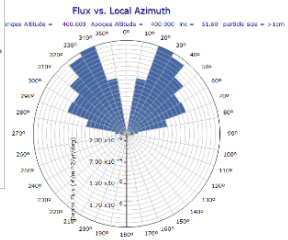
NASA Orbital Debris Program Office (ODPO)

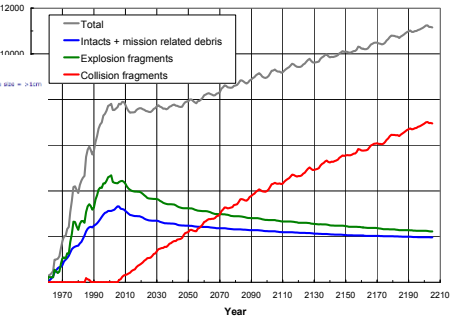


- **The ODPO is the only organization in the U.S. Government conducting a full range of research on orbital debris**
  - This unique NASA capability was established at JSC in 1979 (D. Kessler, B. Cour-Palais, H. Zook, etc.)
  - ODPO's roles and responsibilities are defined in NPR 8715.6
  - ODPO is currently funded through HQ/OSMA
- **ODPO provides technical and policy level support to NASA HQ, OSTP, other U.S. Government agencies and the commercial sector**
- **ODPO represents the U.S. Government in international fora, including the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations**
- **ODPO is recognized as the world leader in environment definition and modeling, and in mitigation policy development**

End-to-End Orbital Debris Activities at ODPO







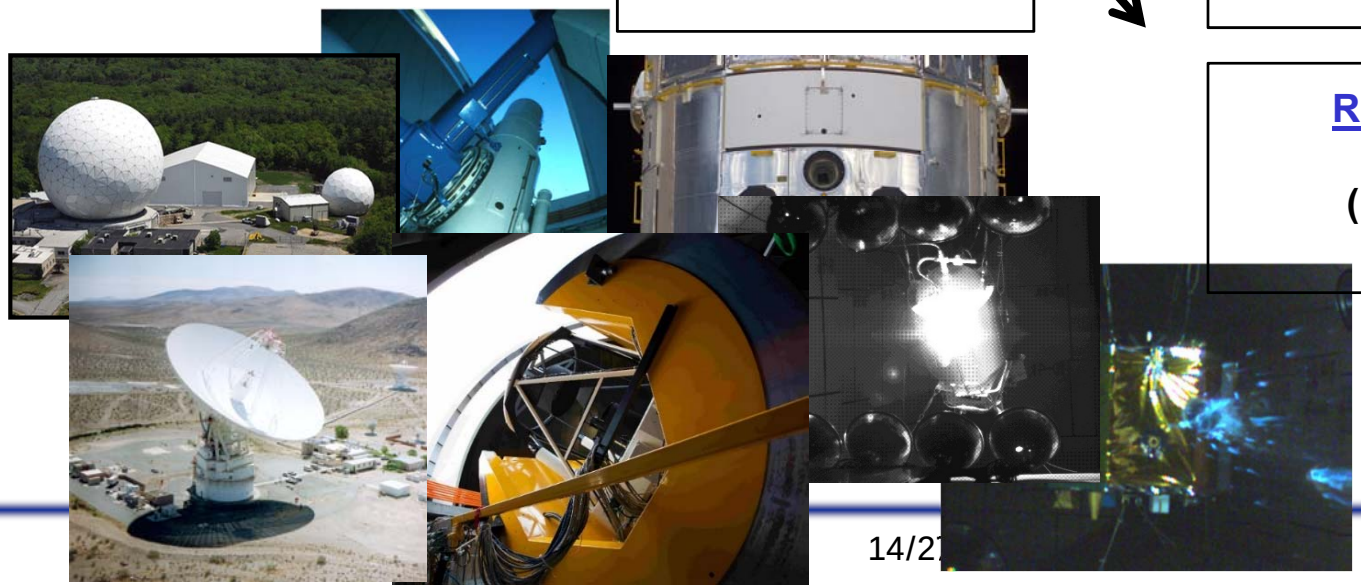
Measurements
Radar
Optical
In-situ
Laboratory

Modeling
Breakup
Engineering
Evolutionary
Reentry

Environment Management
Mitigation
Remediation
Policy
Mission Requirements

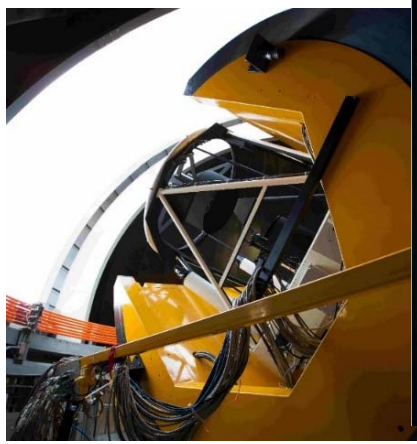
Coordination
U.S. Government
IADC
United Nations

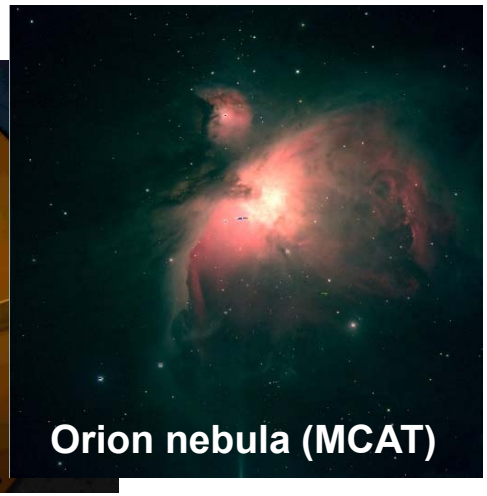
Risk Assessment
Space assets
(ISS, Orion, etc)
Reentry



Meter Class Autonomous Telescope (MCAT)

- **A NASA, U.S. Air Force, and Air Force Research Laboratory joint project**
- **The facility is located on Ascension Island (7° 58' S, 14° 24' W)**
- **The two instruments are a 1.3-m telescope (MCAT) and a 0.4-m Mini-CAT telescope**
  - MCAT: a double horse-shoe DFM telescope with a field-of-view of 41' × 41'
  - Mini-CAT: an Officina Stellare telescope with a field-of-view of 44' × 44'
- **Objectives for operations**
  - Conduct GEO and LEO statistical surveys
  - Detect debris as small as ~13 cm in GEO
  - Characterize low inclination objects in LEO
  - Provide rapid break-up response
  - Support space situational awareness coverage

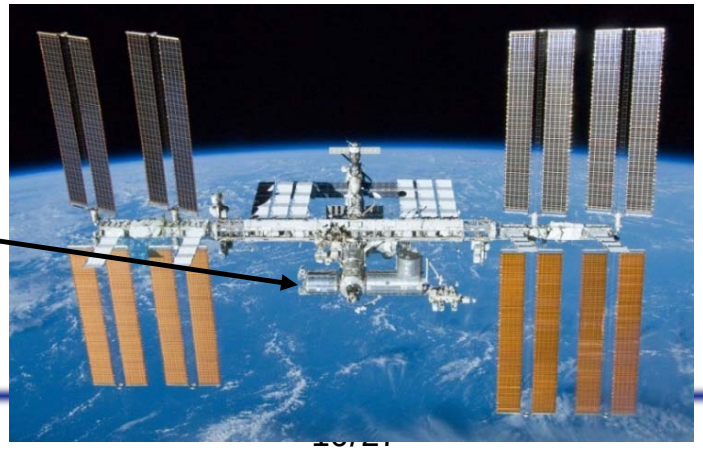




In-Situ Measurements of Small Debris

- **NASA, the U.S. Naval Academy, the U.S. Naval Research Laboratory, Virginia Tech, and the University of Kent (UK) are developing new technologies for in-situ measurements of small debris from space**
  - The Space Debris Sensor (SDS) / Debris Resistive/Acoustic Grid Orbital Navy-NASA Sensor (DRAGONS) combines several particle impact detection principles to measure time, location, speed, direction, energy, and the size of each impacting particle to improve the environment definition for the millimeter and smaller debris population
- **SDS/DRAGONS has been approved by the ISS Program for an October 2017 deployment**

Planned location for SDS/DRAGONS

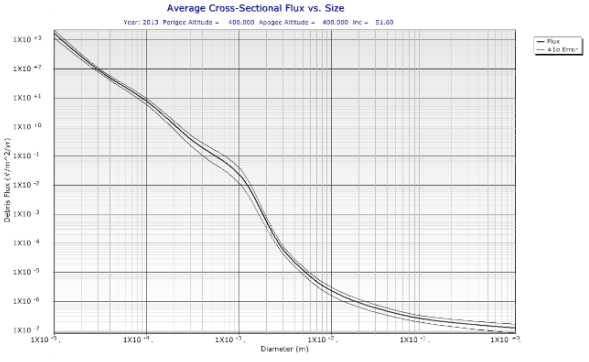


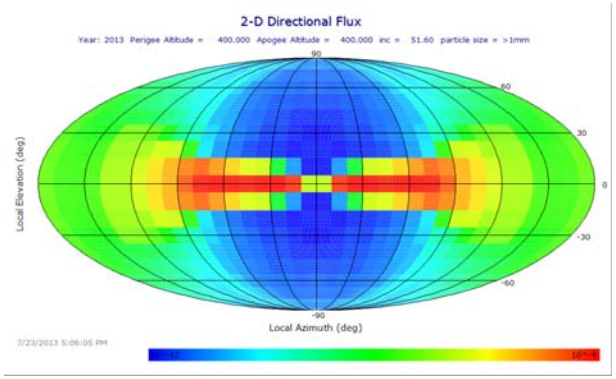
Laboratory-Based Satellite Impact Experiments

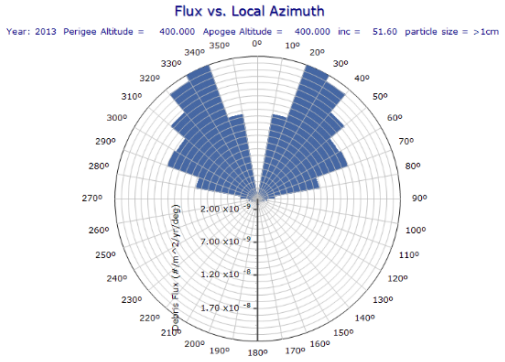
- **To better understand the outcome of an on-orbit collision, NASA, the Air Force Space and Missile Systems Center, the Aerospace Corporation, and the University of Florida are collaborating on a project called DebriSat**
  - Conduct laboratory-based hypervelocity impact experiments on a representative, modern LEO satellite and an upper stage mockup
  - Collect, process, and measure fragments down to a few millimeters in size
  - Use the data to improve satellite breakup models for better protection of the operational spacecraft and to improve space situational awareness of the orbital debris environment

Orbital Debris Engineering Model (ORDEM)

- **For use by spacecraft designers and users to understand the orbital debris impact risks for their spacecraft in Earth orbit**
  - ORDEM provides information on impact rates of orbital debris as a function of size, material density, impact speed, direction, and spacecraft orbit



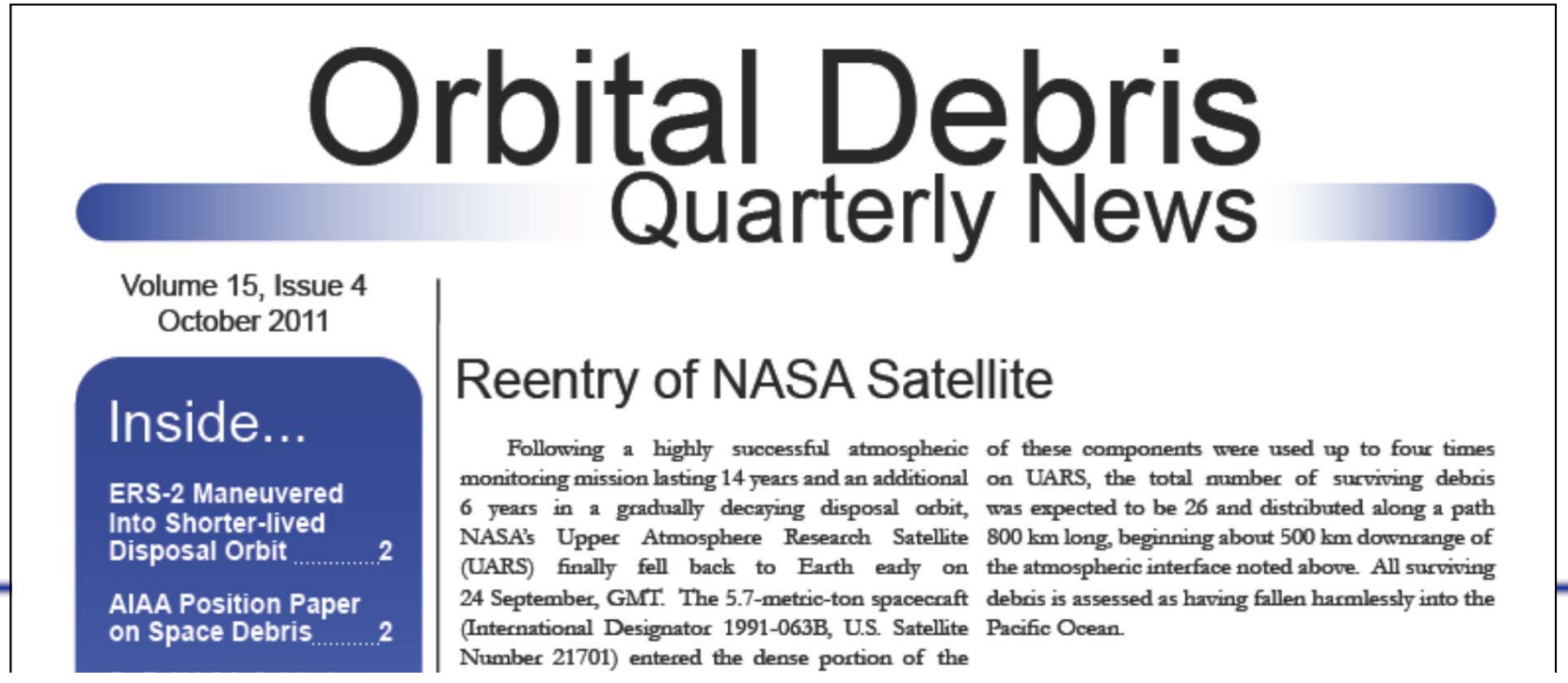




- **ORDEM 3.0 represents NASA's best estimate of the current and near future orbital debris environment**
  - The environment is dynamic and must be updated periodically
  - The model is based on all of NASA and DOD's measurement and modeling activities
    - **JSpOC catalog data, Haystack/HAX/Goldstone ground-based radar data, optical data, and *in situ* data from spacecraft (*e.g.*, Shuttle) returned surfaces**

NASA Orbital Debris Quarterly News

- **The Orbital Debris Quarterly News is a quarterly publication of the NASA Orbital Debris Program Office**
  - It includes the latest events in orbital debris news, research, statistics, project reviews, meeting reports, and upcoming events
  - There are ~1600 subscribers from the global space community
  - It is available at http://www.orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html



Orbital Debris
Quarterly News

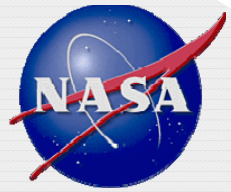
Volume 15, Issue 4
October 2011

Inside...

Reentry of NASA Satellite

Following a highly successful atmospheric monitoring mission lasting 14 years and an additional 6 years in a gradually decaying disposal orbit, NASA's Upper Atmosphere Research Satellite (UARS) finally fell back to Earth early on 24 September, GMT. The 5.7-metric-ton spacecraft (International Designator 1991-063B, U.S. Satellite Number 21701) entered the dense portion of the

of these components were used up to four times on UARS, the total number of surviving debris was expected to be 26 and distributed along a path 800 km long, beginning about 500 km downrange of the atmospheric interface noted above. All surviving debris is assessed as having fallen harmlessly into the Pacific Ocean.



Orbital Debris Mitigation Policy

- Preserving the near-Earth space environment for future generations

Orbital Debris Environment Management

- **"Prevention is better than cure"**
  - (*Prov*.) It is better to try to keep a bad thing from happening than it is to fix the bad thing once it has happened.
- **"An ounce of prevention is worth a pound of cure"**
  - (*Prov*.) It is better/cheaper to stop something bad happening than it is to deal with it after it has happened.

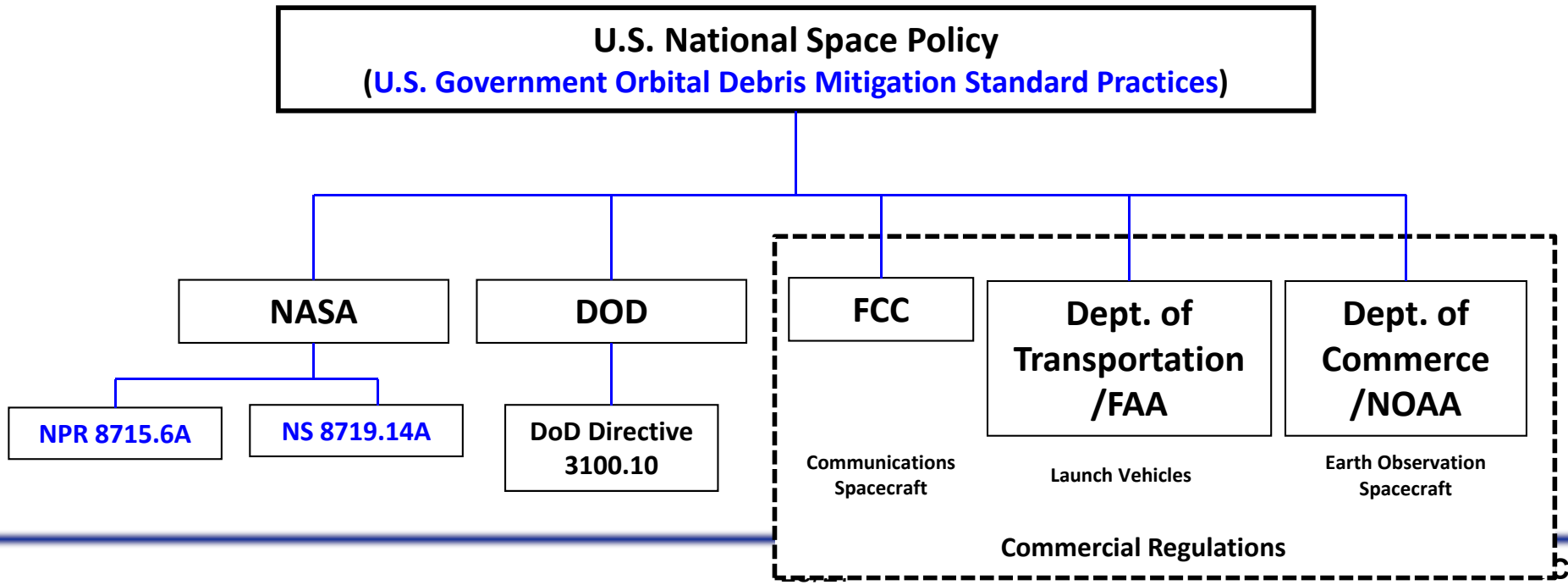
- **Orbital Debris Mitigation ("Prevention")**
  - To prevent the generation of new and long-lived orbital debris in the environment.
- **Orbital Debris Remediation ("Cure")**
  - Active removal of orbital debris already exists in the current environment.

Orbital Debris Mitigation at NASA

- **NASA was the first organization in the world to develop orbital debris mitigation policy and guidelines in the 1990s**
  - NASA Management Instruction (NMI) 1700.8 “Policy for Limiting Orbital Debris Generation” was established in 1993
  - NASA Safety Standard (NSS) 1740.14 “Guidelines and Assessment Procedures for Limiting Orbital Debris” established the first detailed set of mitigation guidelines for NASA missions in 1995
- **The current NASA orbital debris mitigation policy is documented in NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6 (2007)**
  - Specific mission requirements are defined in NASA Technical Standard NS 8719.14, Process for Limiting Orbital Debris (2007)

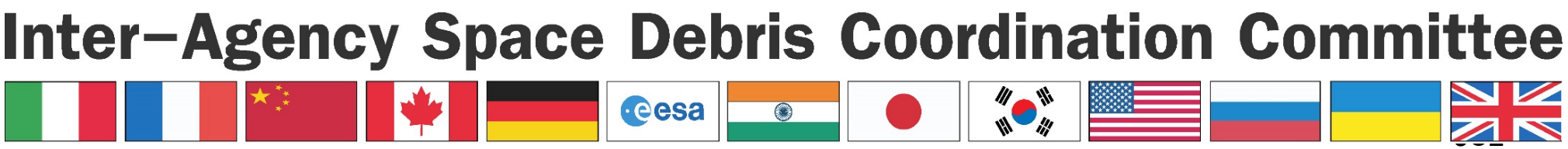
U.S. Government Orbital Debris Mitigation Standard Practices

- **NASA and DOD led the effort to establish the U.S. Government (USG) Orbital Debris Mitigation Standard Practices (approved in 2001)**
- **The U.S. National Space Policies of 2006 and 2010 direct agencies and departments to implement the USG Orbital Debris Mitigation Standard Practices**



Inter-Agency Space Debris Coordination Committee (IADC)

- **The IADC is an international forum of national and multi-national space agencies for the coordination of activities related to space debris.**
  - Current IADC members: ASI, CNES, CNSA, CSA, DLR, ESA, ISRO, JAXA, KARI, NASA, ROSCOSMOS, SSAU, and UKSA.
  - NASA represents the U.S. Government to the IADC. The NASA delegation also includes representatives from State, OSD, AF, FAA, and FCC. The ODPO leads the NASA delegation.
- **IADC is recognized as the technical authority on orbital debris by the international space community.**
- **The IADC developed the first consensus on international orbital debris mitigation guidelines in October 2002; subsequently submitted to the United Nations.**



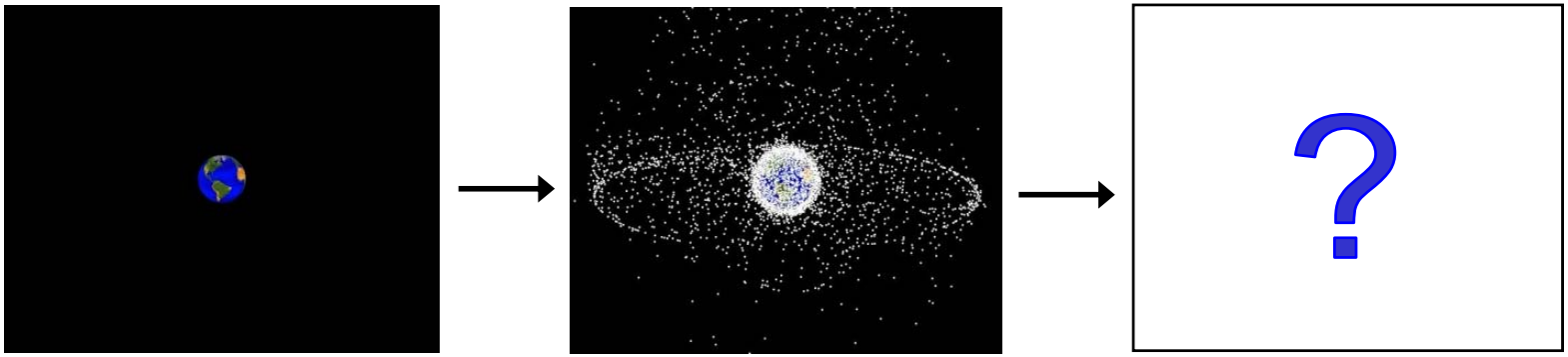
Orbital Debris at the United Nations (UN)

- **Orbital debris has been on the agenda of the Scientific and Technical Subcommittee (STSC) of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994.**
  - The NASA Chief Scientist for Orbital Debris is a member of the U.S. delegation. He also gives a presentation on the status of the orbital debris environment and highlights of the NASA orbital debris research activities at the annual STSC meeting.
- **STSC Member States adopted a set of space debris mitigation guidelines similar to the IADC guidelines in Feb. 2007, followed by adoption by COPUOS in Jun. 2007 and by the full UN General Assembly in Dec. 2007.**
- **There is an on-going effort by COPUOS to develop a new set of guidelines on the long-term sustainability of outer space activities.**

Forward Challenges

- **Conduct space-based in-situ measurements on millimeter-sized orbital debris populations in low Earth orbit to better protect critical NASA assets**
- **Improve compliance with the existing orbital debris mitigation requirements and guidelines at NASA, in the United States, and by the international space community**
- **Develop near- and long-term cost-effective orbital debris mitigation and remediation strategies**
- **Advance space situational awareness coverage**
- **Explore options for space traffic management**

Preserving the Near-Earth Space Environment for Future Generations



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